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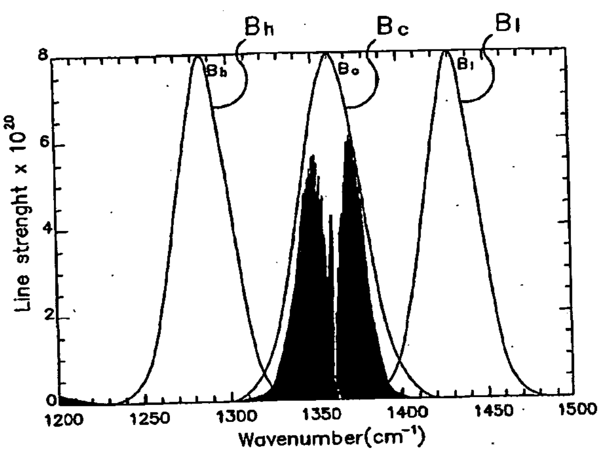
(54) Title: SULPHUR DIOXIDE DETECTION METHOD



(57) Abstract: There is disclosed a method of detecting sulphur dioxide clouds. The method comprises measuring infrared radiation at a viewing elevation at or above the horizon and at a key wavelength at which there is a sulphur dioxide feature and in the vicinity of which there is a region where the amount of infrared radiation from water vapour in the atmosphere varies in accordance with a predetermined relationship, measuring radiation at two or more subsidiary wavelengths in said region, determining the amount of radiation from water vapour at the key wavelength from the measured radiation at the subsidiary wavelengths using the predetermined relationship, and determining whether a sulphur dioxide cloud is present from the measured infrared radiation at the key wavelength and the determined amount of radiation from water vapour.

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SULPHUR DIOXIDE DETECTION METHOD

Field of the Invention

The invention relates to a sulphur dioxide detection method and apparatus.

Background to the Invention

Volcanic ash and sulphur dioxide clouds constitute a serious hazard to aircraft even after the clouds have moved from the site of a volcanic eruption. Apart from containing ash particles, the clouds include gases such as SO_2 which after a few days oxidises and hydrolises to form sulphuric acid droplets, either as an ash-acid mixture or as a coating over ash particles. Both the ash particles and the sulphuric acid droplets of volcanic ash clouds are capable of causing significant damage to and possible loss of an aircraft which encounters an ash cloud.

A number of aircraft encounters with volcanic ash clouds or sulphur dioxide clouds have been recorded in the past where significant damage has occurred. It will be appreciated that the sulphur dioxide may be found in areas separate from the volcanic ash. In the year 2000, a National Aeronautics and Space Administration (NASA) DC-8 Airborne Sciences research airplane flew through what was described as a diffuse volcanic ash cloud from the mount HEKLA Volcano when flying from Edwards, California to Kiruna, Sweden. The ash cloud was not visible to flight crew, however, the research airplane carried sensitive research equipment which was capable of detecting the sulphur dioxide. In-flight checks and post-flight visual inspections revealed no damage to the airplane. However, detailed examination of the engines revealed damage to some of the turbine cooling passages. Furthermore, high

levels of sulphur were found in the oil.

It seems likely that this ash cloud actually was predominantly a sulphur dioxide cloud. Even if it was not, it raises the possibility that an aircraft can fly through sulphur dioxide without passing through ash. The post encounter treatment of the engine in the case of sulphur dioxide encounter would be different to and considerably cheaper than the equivalent treatment required of an engine during an ash encounter.

Accordingly, it would be desirable to provide a sulphur dioxide cloud detection technique.

Summary of the Invention

The present invention relates to a method of detecting sulphur dioxide clouds comprising:

measuring infrared radiation at a viewing elevation at or above the horizon and at a key wavelength at which there is a sulphur dioxide feature and in the vicinity of which there is a region where the amount of infrared radiation from water vapour in the atmosphere varies in accordance with a predetermined relationship;

measuring radiation at two or more subsidiary wavelengths in said region;

determining the amount of radiation from water vapour at the key wavelength from the measured radiation at the subsidiary wavelengths using the predetermined relationship; and

determining whether a sulphur dioxide cloud is present from the measured infrared radiation at the key wavelength and the determined amount of radiation from water vapour.

Preferably, said subsidiary wavelengths are located either side of said key wavelength.

The inventor has determined that the key wavelength should be one of 7.3μm and 8.6μm and that 7.3μm is the preferred key wavelength.

Where the key wavelength is 7.3μm, it is preferred that subsidiary wavelengths at ±0.5μm are used. The inventor has established that for the region of these wavelengths the predetermined relationship is that radiation from water vapour varies in a substantially linear manner. Accordingly, the radiation from water vapour at the key wavelength can be interpolated from the radiation at the subsidiary wavelengths on the basis of this predetermined relationship. The inventor has also established that there is substantially less SO_2 absorption at this wavelength.

The method may also involve compensating for background SO_2 in the atmosphere.

The invention also provides a detection apparatus for detecting a sulphur dioxide cloud comprising:

measurement means that measures infrared radiation at a viewing elevation at just below, or above the horizon and at a key wavelength at which there is a sulphur dioxide feature and in the vicinity of which there is a region where the amount of infrared radiation from water vapour in the atmosphere varies in accordance with a predetermined relationship, said measurement means also measuring infrared radiation at two or more subsidiary wavelengths in said region; and

processing means for determining the amount of radiation from water vapour at the key wavelength from the measured radiation at the subsidiary wavelengths using the predetermined relationship and determining whether a sulphur dioxide cloud is present from the measured infrared radiation at the key wavelength and the

determined amount of radiation from water vapour; and

output means for generating an output signal indicative of the presence of a sulphur dioxide cloud when a sulphur dioxide cloud is present.

The inventor has also determined that the method and apparatus of the present invention can be used to detect sulphur dioxide clouds from the ground or from an aircraft.

Brief Description of the Drawings

Figure 1 illustrates the SO_2 absorption feature in the region 1200cm^{-1} to 1500cm^{-1} and the preferred measurement wavelengths of the invention;

Figure 2 is a schematic diagram of a SO_2 detection apparatus of the preferred embodiment;

Figure 3 illustrates two modes of operation of the apparatus;

Figure 4 is a schematic diagram of apparatus to be used from an aircraft;

Figures 5a - 5c represent normal climatic conditions;

Figures 6a and 6b represent variations on normal conditions to allow testing of the invention;

Figure 7 represents variations in SO_2 for testing;

Figure 8 shows variation in temperature with SO_2 concentration; and

Figure 9 shows temperature plotted as a function of absorber amount.

Description of the Preferred Embodiment

Herein, the term "key wavelength" is used to refer to a wavelength at which there is an appropriate SO_2 feature.

Persons skilled in the art will appreciate that a "wavelength" in the context of this specification does not imply a single wavelength but rather encompasses a band of radiation. Typically the width of the band will depend on the filter used to observe/measure light at the wavelength of interest. The numerical figures given in this specification are used to denote, in general terms, the centre of such bands, however, it will be appreciated by persons skilled in the art that some variation of the centre wavelength is possible.

The term "subsidiary wavelength" is used to refer to a wavelength in a region in the vicinity of the key wavelength where a relationship can be established between radiation from water vapour at two or more subsidiary wavelengths and radiation from water vapour at the key wavelength.

The preferred embodiment provides a method and apparatus that allows identification of sulphur dioxide clouds in the free atmosphere. The apparatus of the preferred embodiment uses an infrared detector, interference filters and focussing optics. The filters divide radiation within the band between 6.8 and 8.1 μm into three narrow bands. The central band corresponds to a strong SO_2 absorption feature caused by the anti-symmetric stretch of the SO_2 molecule at 7.3 μm. The other bands are above and below this feature. The central band B_c, is sensitive to SO_2 concentrations. The lower band, B_l and higher band B_h, are used to account for the effects of water vapour on the absorption in band B_c.

Accordingly, B_c is the key wavelength and B_l and B_h are the subsidiary wavelengths in the preferred embodiment.

Figure 1 illustrates the absorption feature due to SO_2 for the infrared region extending from 1200 cm^{-1} (8.33 µm) to 1500 cm^{-1} (6.67 µm). The ordinate in this plot is line strength and the abscissa is wavenumber (cm^{-1}; wavelength in µm = 10,000/wavenumber in cm^{-1}). Also, shown are three idealised filter response functions which isolate radiation within the three narrow regions corresponding to: B_h (7.633-8.065 µm) B_c (7.143-7.57 µm) and B_l (6.897-7.042 µm).

The response functions are normalised to unity and scaled appropriately for plotting. The central wavenumber for the SO_2 absorption is 1363 cm^{-1} and the band extends from about 1320 cm^{-1} to about 1390 cm^{-1}. A filter covering this region responds to all the radiation from this band; whether the SO_2 feature be due to absorption or emission. In the case of a detection apparatus viewing a cold background, i.e. viewing from the ground to space or from an aircraft towards the horizon, there would be more radiation in this band in the presence of the SO_2 cloud than if it were absent.

In practice, water vapour and clouds also absorb and emit radiation in the region 7-8 µm. The inventor has realised that the two bands positioned either side of the central band can be used to eliminate the effects of water vapour.

Water vapour absorbs and emits radiation throughout the region 7-8 µm. The amount of radiation absorbed or emitted depends on the amount of water vapour and on its location in the atmospheric column. Water vapour near the boundary of the earth's surface is generally warm and abundant. Water vapour near the tropopause (i.e. at jet aircraft cruising altitudes) is cold and sparse. The central band B_c of the SO_2 detector of the preferred embodiment responds to radiation due to

both SO_2 and water vapour. The lower and higher bands B_c, B_h of the detector however, are only sensitive to water vapour. The inventor has determined that the radiation from water vapour in the region surrounding B_c behaves in a sufficiently linear manner to enable it to eliminate the effects of water vapour on the central band sufficiently for the purpose of detecting a sulphur dioxide cloud. The Planck blackbody radiation from B_l and B_h are linearly interpolated to estimate the radiation detected in B_c due to water vapour only. This radiation amount is subtracted from the radiation actually measured by B_c. The residual amount is due to SO_2. Accordingly the preferred embodiment utilises a predetermined relationship that water vapour behaves in a linear manner. Persons skilled in the art will appreciate that other predetermined relationships could be used, for example, relationships that are approximately linear.

A schematic of the detection apparatus is shown for illustrative purposes in Figure 2. The detection apparatus 6 consists of four major components:

- Fore-optics 1 that focus a beam of incoming infrared radiation onto a detector.
- A filter wheel 2 consisting of at least three narrow band interference filters that isolate radiation into the bands: B_l, B_c and B_h.
- An infrared detector array 3 sensitive to radiation in the 7-8 μm region.
- Processing means 4 for processing the detector signal to determine whether SO_2 and hence a sulphur dioxide cloud is present.

Figure 3 is a schematic diagram illustrating two modes of operation of a detection apparatus 6 that senses infrared radiation in order to detect SO_2 clouds. A first mode assumes that the detection apparatus 6 is on board an aircraft 7 and views the SO_2 cloud ahead at a small angle

to the horizontal. The second mode assumes that the detection apparatus 6 is based on the ground and views the cloud at a large angle to the horizontal (e.g. zenith viewing).

The detection apparatus of the preferred embodiment may be operated from the ground viewing the sky above or from an aircraft viewing forwards at just below or above the horizon. The principal mode of operation is anticipated to be from an aircraft with the instrument having an unobstructed view of the atmosphere ahead of the aircraft as the inventor has established that the method works best when water vapour path amount is less than 1g cm^{-2}. For example, at heights over 3000 m or in dry atmosphere water vapour path is defined as the integral of the water vapour concentration with distance along the line of sight between instrument and target. Ideally the view should be horizontal or a few degrees (3-5°) above the horizon, so that the background radiation is cold. Typically, aircraft fly with their nose at an angle of about 3 degrees to horizontal. However, the processor 4 can be configured to account for changes in viewing zenith angle, making the technique insensitive to the viewing direction. For the case of a detection apparatus 6 viewing ahead of an aircraft at a zenith angle of Z degrees, the detection apparatus 6 provides three signals to the processor 4. A synthetic signal corresponding to the amount of radiation from water vapour is determined through linear interpolation of the signals from B_l and B_h. This signal labeled $\hat{B}_c$ is compared to the signal from B_c.

The processor 4 then computes the SO_2 amount at the key wavelength B_o using $\hat{B}_c$ and the original signal B_c. The processor 4 uses pre-defined look-up tables that account for standard atmospheric conditions (tropical, mid-latitude, and polar) and the viewing geometry to compensate for background SO_2. The detector array 3

provides an image of the SO_2 amount with a spatial resolution that depends on the exact number of detector elements in the array (320x240 is recommended) and the distance to the SO_2 cloud. Distance information is supplied by the detection apparatus 6, however, the SO_2 anomaly will be detected at distances of up to several 100 kms depending on the cruising altitude and clarity of the atmosphere ahead. The detection apparatus 6 produces an output 5, for example in the form of an amount of SO_2 or an alarm signal indicating the presence of sufficient SO_2 to pose a problem. The alarm signal may cause an audible or visual alarm in an aircraft.

Figure 4 illustrates how the apparatus works in the case of being mounted in an aircraft.

In addition to signals from the detector 3 the processor 4 also receives aircraft altitude information 8 from the aircraft and standard atmosphere information 9 from a memory associated with the processor.

__Examples__

A sophisticated radiative transfer model-MODTRAN (Berk, *et al.*, 1989) is used to model the response expected from a single-element detector viewing arealistic atmosphere. The viewing geometry is varied in the simulations to account for viewing from below the SO_2 cloud, viewing from above, and viewing at a small angle along a nearly horizontal path. The amount of SO_2 is varied, as is the main other gaseous absorber in the region-water vapour. We refer to the amount of SO_2 as the cloud thickness.

__1. Model Atmosphere__

Vertical profiles of the model atmosphere used in

the simulations are shown in Figure 5 and variations used to test the present invention are shown in Figure 6 and Figure 7.

(a) *Temperature*

The temperature profile is shown in Figure 6a. Varying the profile has little effect on the retrieval and detection algorithm because the algorithm uses differences in temperatures. No further simulations were performed on this parameter because of its insensitivity.

(b) *Water vapour*

Water vapour was varied by increasing the amounts in the lowest layers from less than 0.1 cm of precipitable water to more than 3 cm. No effect was found on the detection or retrieval because the water vapour lies below the SO_2 cloud. Water vapour was also increased in the layer that contained the SO_2 and this has a major effect. The perturbed water vapour profile is shown in Figure 6b.

(c) Sulphur dioxide

The vertical profile of the background SO_2 is taken from the US standard atmosphere. The profile corresponds to a well-mixed gas with a constant vertical concentration of 10^{-5} ppmV (parts per million by volume). Perturbed profiles, with increasing SO_2 concentration, are shown in Figure 7. Eight profiles are shown. The integrated amount of SO_2 in a vertical column for the profiles varies from 10 milli atm-cm to 100 milli atm-cm. Depending on the pathlength travelled the total absorber amount can be much larger. Results for SO_2 absorber amounts of more than 1000 milli atm-cm are given.

<u>2. Viewing the SO_2 cloud along horizontal paths</u>

For the purpose of example, model simulations have been performed for the case of horizontal viewing from a platform (e.g. an aircraft) directly ahead and towards an SO_2 cloud. The viewing direction is assumed to be horizontal at the altitude of the platform (8 km, or ≈26,000 feet is assumed). The cloud thickness (as measured in the viewing direction) is varied from 10 km to 500 km and the concentration within the cloud is varied from background levels to ≈0.1 ppmV. This range of concentration covers the smallest eruptions (that are likely to reach these heights, e.g. Hekla-style eruptions) to the largest observed this century (e.g. Pinatubo-style eruptions). The results of these model simulations are summarised in two figures. Figure 8 shows the variation of the temperature anomaly (the temperature difference between the synthetic signal and the measured signal as a function of cloud thickness).

The family of curves 20-27 generated from the modelling are lines of constant concentration for SO_2 concentration varying from 0.0136 ppmV 20 to 0.1083 ppmV 27. The points that lie on vertical lines correspond to lines of constant cloud thickness. As the cloud thickens the curves follow the same trend with increasing anomalous signal until the cloud starts to become opaque. At this point, which varies with SO_2 concentration, the temperature anomaly increases towards a limiting value ($\Delta T \approx -2$ K). Note that the opaque limit is reached either by increasing concentration or increasing cloud thickness, since both quantities increase optical depth and hence absorption. Beyond a thickness of 500 km, the cloud is essentially opaque and the radiative process changes from absorption to emission.

Figure 9 provides an alternate way of understanding the physical processes involved in SO_2

detection. Here the temperature anomaly is plotted as a function of absorber amount. The plot indicates that for a given anomaly, several values of absorber amount are possible, depending on the cloud thickness and concentration. Thus, it is not possible to uniquely quantify the absorber amount from the temperature anomaly without knowing either the concentration or the cloud thickness. In practice it is not necessary to know these quantities, as the purpose of the invention is to detect the presence of SO_2 gas in the free atmosphere, rather than quantify the amount. The modelling does give an indication of the limits within which detection of SO_2 is possible. At the lower end, for cloud thicknesses of 10 km or less, the SO_2 concentration must be larger than $\approx$0.06 ppmV. This corresponds to an absorber amount of $\approx$25 milli atm-cm. SO_2 clouds that intercept air-routes (i.e. heights >20,000 feet) will have horizontal dimensions of 10's of kilometres and absorber amounts well in excess of 25 milli atm-cm would be expected.

Persons skilled in the art will appreciate that various modifications may be made to the preferred embodiment without departing from the scope of the appended claims.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of detecting sulphur dioxide clouds comprising:

measuring infrared radiation at a viewing elevation at or above the horizon and at a key wavelength at which there is a sulphur dioxide feature and in the vicinity of which there is a region where the amount of infrared radiation from water vapour in the atmosphere varies in accordance with a predetermined relationship;

measuring radiation at two or more subsidiary wavelengths in said region;

determining the amount of radiation from water vapour at the key wavelength from the measured radiation at the subsidiary wavelengths using the predetermined relationship; and

determining whether a sulphur dioxide cloud is present from the measured infrared radiation at the key wavelength and the determined amount of radiation from water vapour.

2. A method as claimed in claim 1, wherein said method is performed from a position or position where the water vapour path amount is less than 1g cm^{-2}.

3. A method as claimed in claim 1, wherein said subsidiary wavelengths are located either side of said key wavelength.

4. A method as claimed in claim 1, wherein said key wavelength is one of 7.3μm and 8.6μm.

5. A method as claimed in claim 1, wherein the key wavelength is 7.3μm.

6. A method as claimed in claim 4, wherein subsidiary wavelengths at ±0.5μm are used.

7. A method as claimed in claim 5, wherein subsidiary wavelengths at ±0.5μm are used.

8. A method as claimed in claim 5, wherein determining the amount of the radiation from water vapour at the key wavelength is performed by a linear interpolation based on the radiation measured at the subsidiary wavelengths.

9. A method as claimed in claim 1, further comprising compensating for background sulphur dioxide in the atmosphere.

10. A method as claimed in claim 1, wherein said method is performed from an aircraft.

11. A method as claimed in claim 2, wherein said method is performed from the ground.

12. A detection apparatus for detecting a sulphur dioxide cloud comprising:

measurement means that measures infrared radiation at a viewing elevation at just below, or above the horizon and at a key wavelength at which there is a sulphur dioxide feature and in the vicinity of which there is a region where the amount of infrared radiation from water vapour in the atmosphere varies in accordance with a predetermined relationship, said measurement means also measuring infrared radiation at two or more subsidiary wavelengths in said region; and

processing means for determining the amount of radiation from water vapour at the key wavelength from the measured radiation at the subsidiary wavelengths using the predetermined relationship and determining whether a sulphur dioxide cloud is present from the measured infrared radiation at the key wavelength and the determined amount of radiation from water vapour; and

output means for generating an output signal indicative of the presence of a sulphur dioxide cloud when a sulphur dioxide cloud is present.

13. Apparatus as claimed in claim 12, wherein said subsidiary wavelengths are located either side of said key wavelengths.

14. Apparatus as claimed in claim 12, wherein said key wavelength is one of 7.3µm and 8.6µm.

15. Apparatus as claimed in claim 12, wherein the key wavelength is 7.3µm.

16. Apparatus as claimed in claim 14, wherein said subsidiary wavelengths are at ±0.5µm.

17. Apparatus as claimed in claim 15, wherein said subsidiary wavelengths are at ±0.5µm.

18. Apparatus as claimed in claim 15, wherein determining the amount of the radiation from water vapour at the key wavelength is performed by a linear interpolation of the radiation measured at the subsidiary wavelengths.

19. Apparatus as claimed in claim 12, wherein said processing means compensates for background sulphur dioxide in the atmosphere.

20. An aircraft having a detection apparatus as claimed in claim 12.

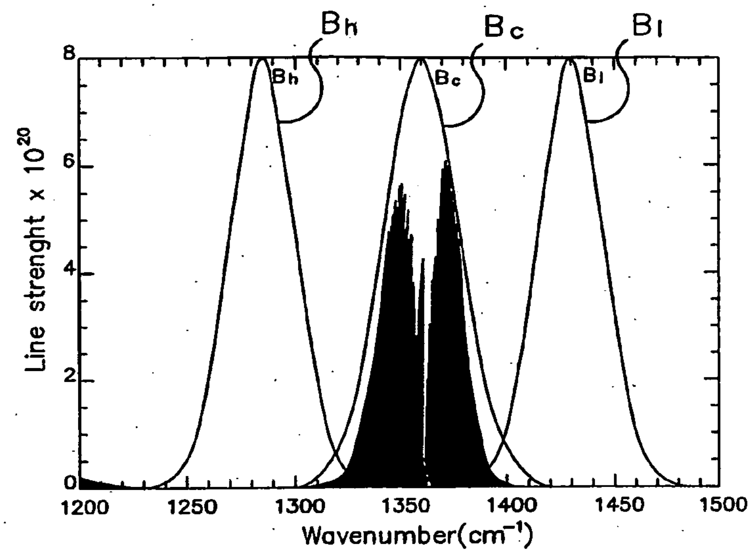

FIGURE 1

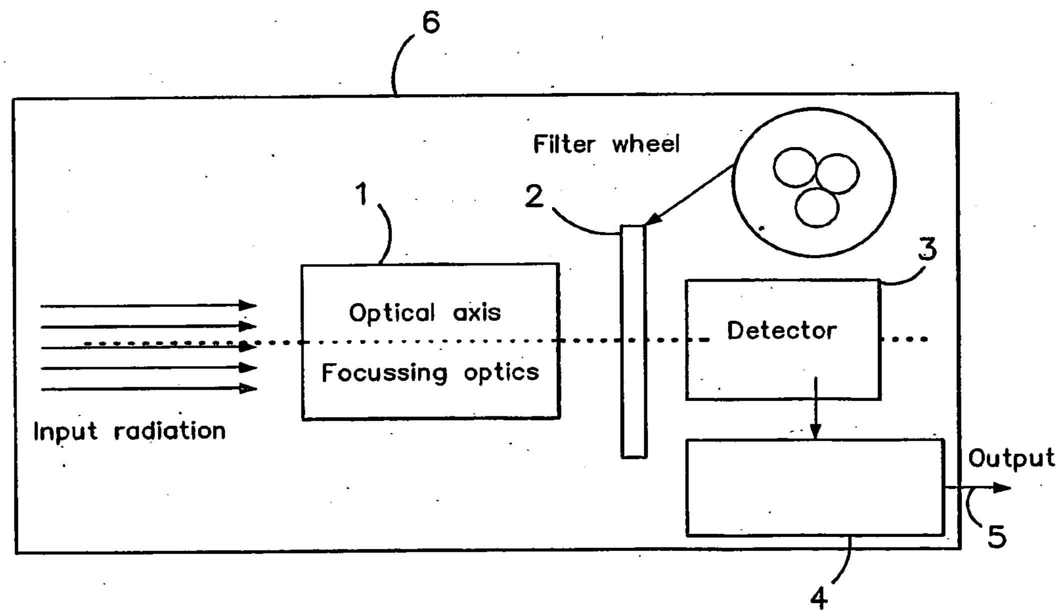

FIGURE 2

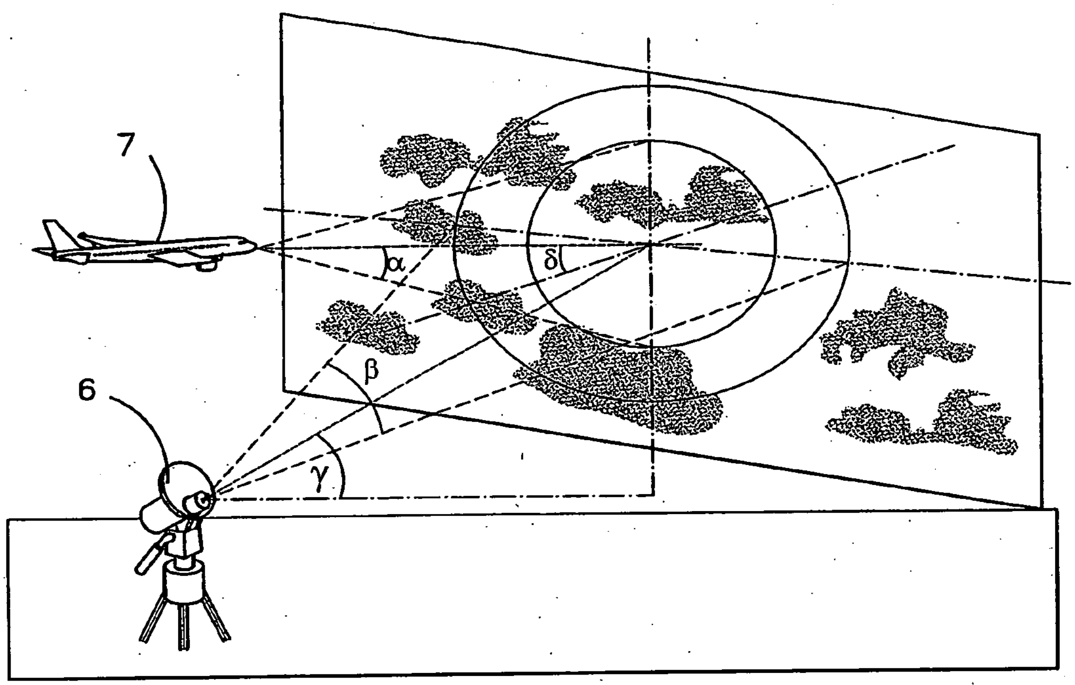

FIGURE 3

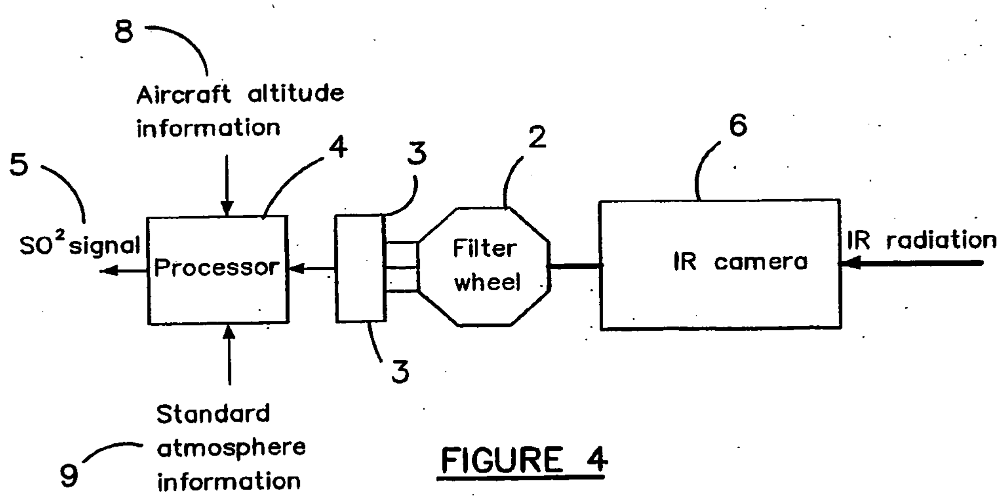

FIGURE 4

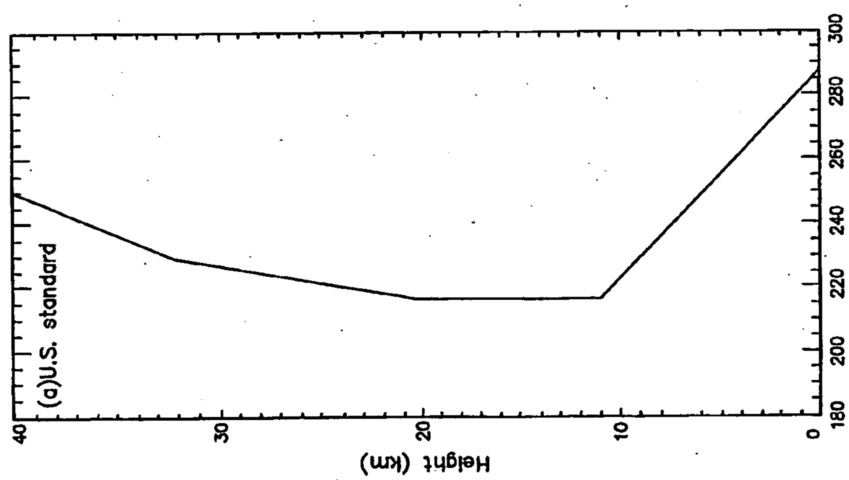

FIGURE 5a

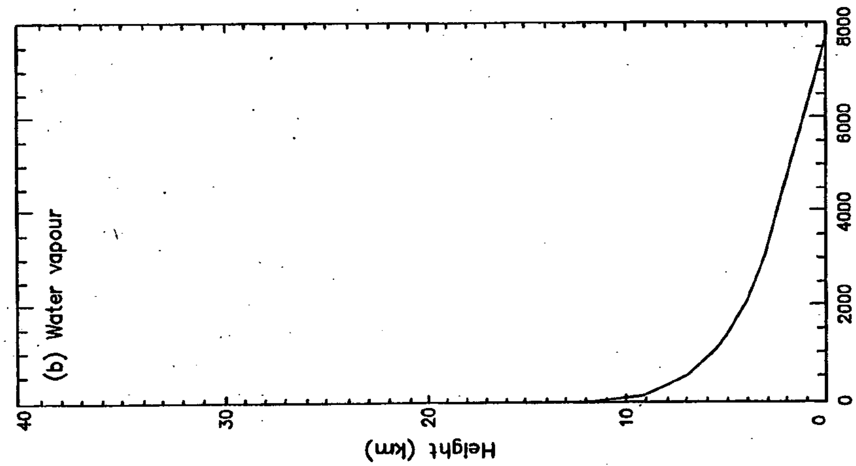

FIGURE 5b

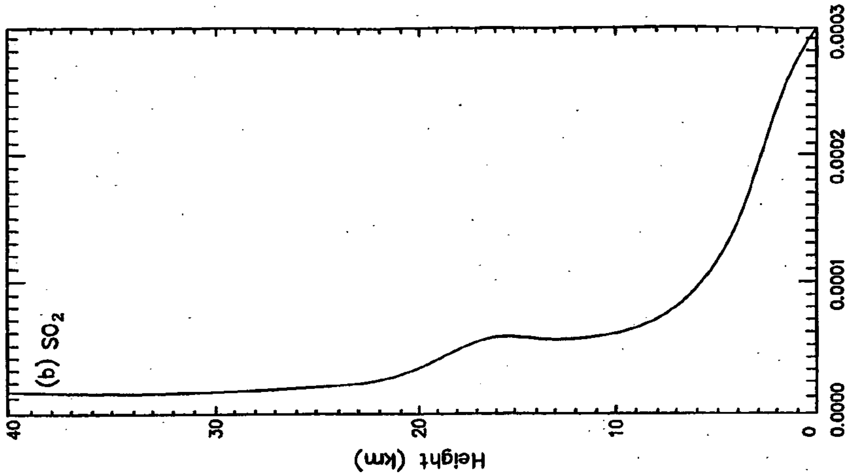

FIGURE 5c

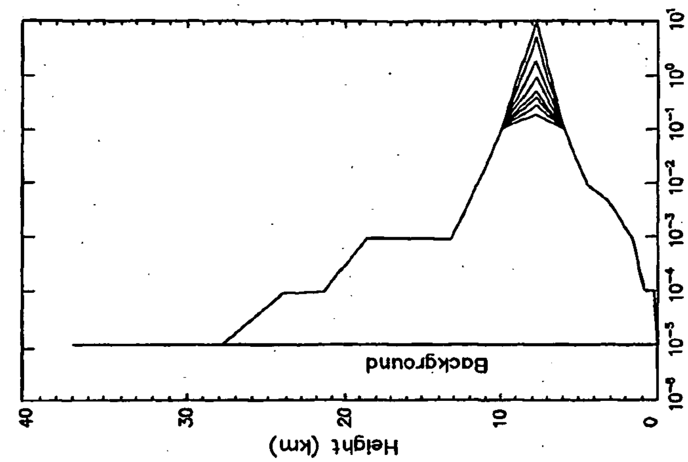

FIGURE 6c

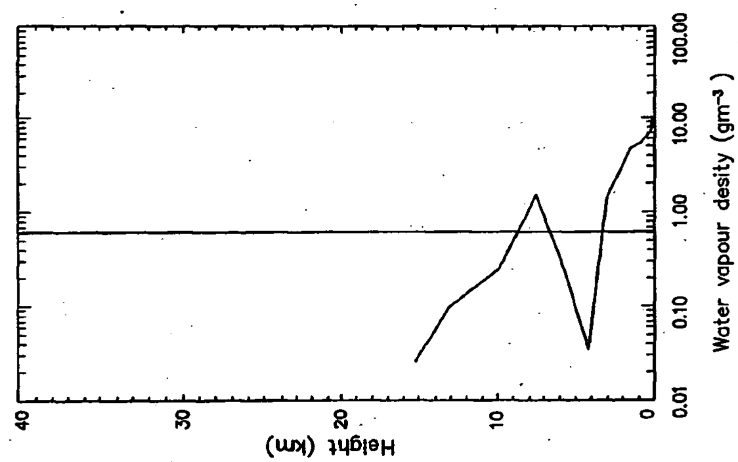

FIGURE 6b

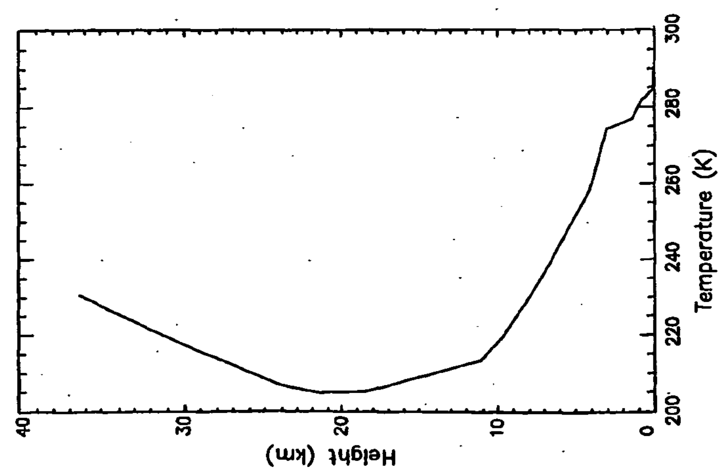

FIGURE 6a

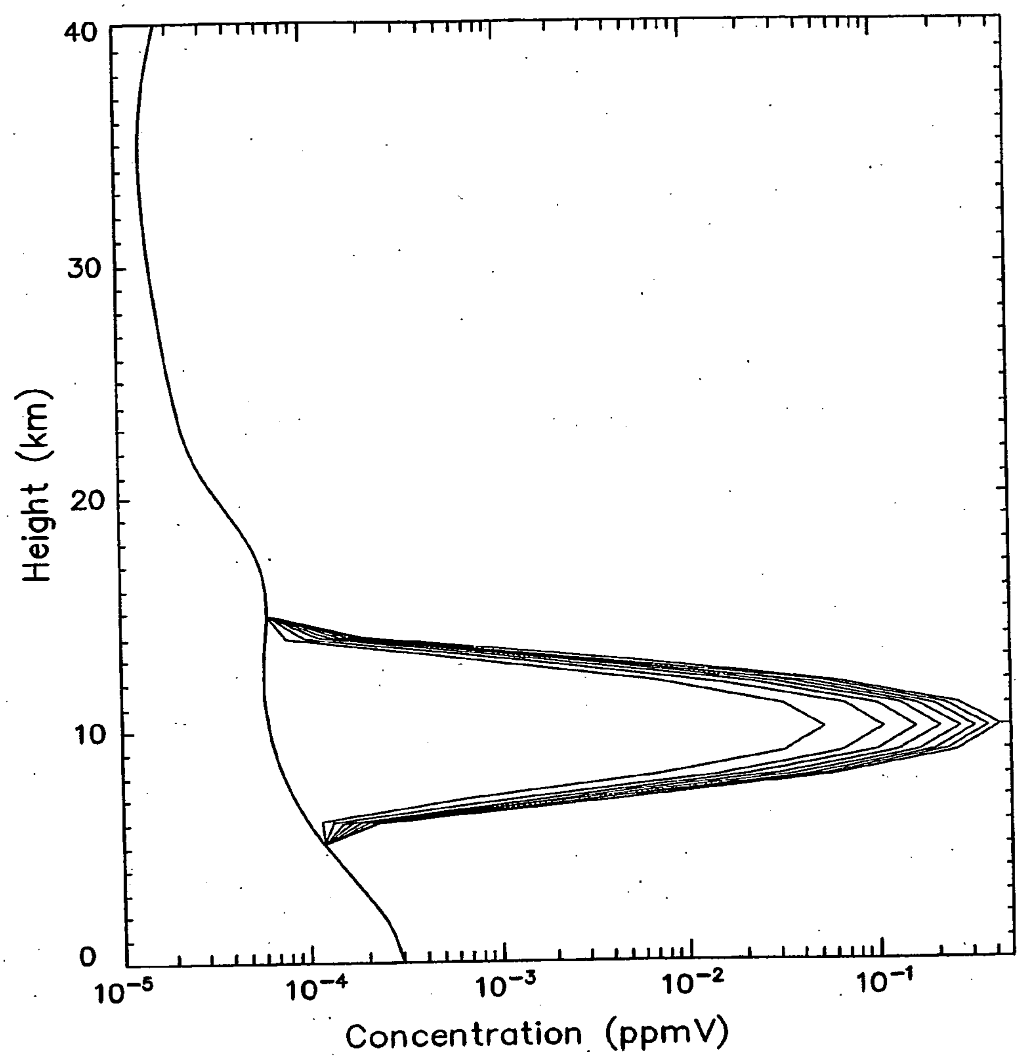

FIGURE 7

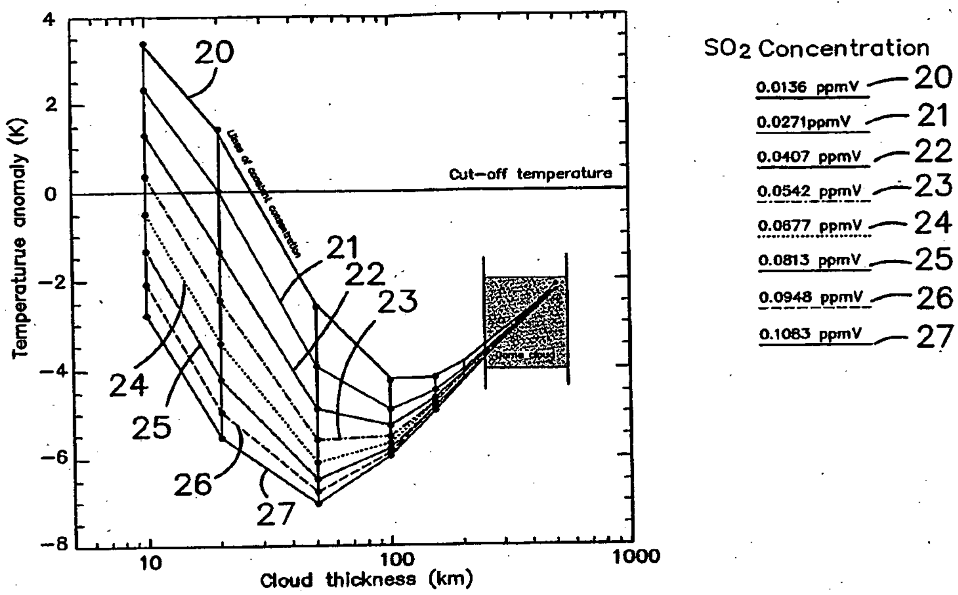

FIGURE 8

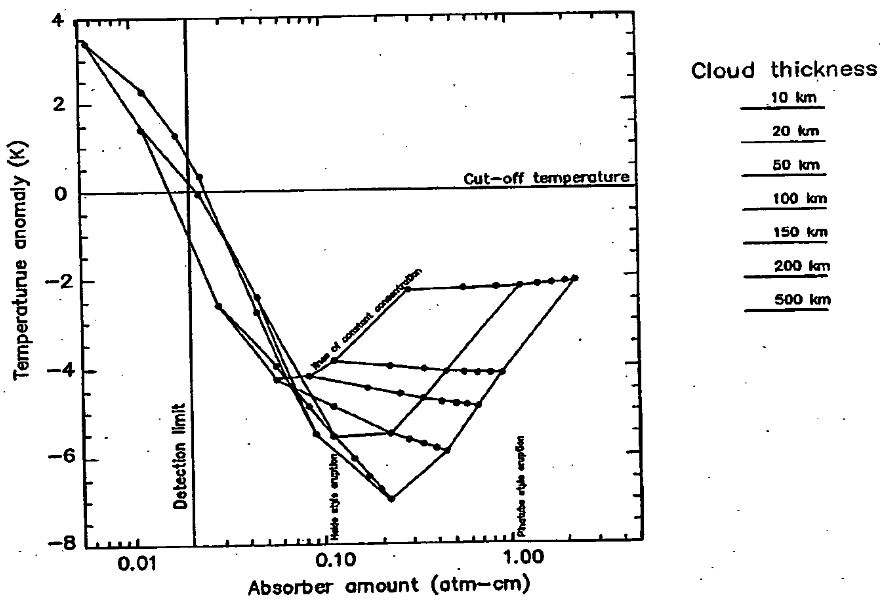

FIGURE 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2005/000035

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. [7]: G01N 21/35, G01J 3/42, 3/45, G08G 5/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

- DWPI; SO2 OR SULPHUR DIOXIDE; WATER OR H2O OR CLOUD? OR MOISTURE OR HUMIDITY; DETECT+ OR IMAG+ OR SENS+ OR DISTINGUISH+ OR IDENTIF+OR G01N-021/IC; INFRARED OR IR OR TIR; TERRESTRIAL OR AIRBORNE OR AHEAD OR SKY OR "GROUND BASED", SUBTRACT+ OR COMPENSAT+ OR CORRECT+ OR DISCRIMINAT+ OR ELIMINAT+; SPECTR+, +BAND+ OR WAVENUMBER? OR WAVELENGTH? OR ABSORPTION OR EMISSION OR FEATURE? OR SIGNATURE? OR LINE? OR FREQUENC+ OR FILTER+ OR +CHANNEL? OR MULTISPECTR+ and similar keywords
- Google Scholar: SULPHUR DIOXIDE; WATER; DETECT; THERMAL INFRARED and similar combinations of keywords

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PRATA A. J. , ROSE W.I., SELF S. and O'BRIEN D.M., Global, Long-Term Sulphur Dioxide Measurements From TOVS Data: A New Tool for Studying Explosive Volcanism and Climate, *Volcanism and the Earth's Atmosphere*, Alan Robock, Clive Oppenheimer, editors; Geophysical Monograph 139, ISBN 0-87590-998-1; Copyright 2003 by the American Geophysical Union; pages 75-92, see in particular Figure 1 and its description; section 3, including subsections 3.3-3.4	1-20

[X] Further documents are listed in the continuation of Box C   [X] See patent family annex

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- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 2005	30 MAR 2005
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **GREG POWELL** Telephone No : (02) 6283 2308

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5654700 A (PRATA et al.) 5 August 1997 The whole document and in particular the paragraph bridging columns 4 and 5, Figure 5, Claims 10 and 17	1-20
P, X	WATSON I.M., REALMUTO V.J., ROSE W.I., PRATA A.J., BLUTH G.J.S., GU Y., BADER C.E., YU T., Thermal infrared remote sensing of volcanic emissions using the moderate resolution imaging spectroradiometer, *Journal of Volcanology and Geothermal Research 135* (2004) pages 75-89, (available online from 18 May 2004); see Figure 1(D) and Table 1 (channels 28 and 29)	1-20
A	PUGNAGHI S., TEGGI S., CORRADINI S., BUONGIORNO M.F., MERUCCI L., BOGLIOLO M.P., Estimation of SO_2 abundance in the eruption plume of Mt. Etna using two MIVIS thermal infrared channels: a case study from the Sicily-1997 Campaign, *Bull Volcanol* (2002) 64, pages 328-337, see abstract	
A	US 3805074 A (MCCORMACK) 16 April 1974 Abstract, columns 5-6	
A	Patents Abstracts of Japan JP 60-011122 A (SHIMADZU CORP) 21 January 1985 Abstract	
A	Derwent Abstract Accession No 83-754335/36, Class S03, EP 0087077 A (SIEMENS AG) 31 August 1983 Abstract	
P, A	US 6822236 B1 (NELSON et al.) 23 November 2004 Abstract, Column 5, lines 12-21 and entire Column 8	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU2005/000035

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member					
US	5654700	AU	76657/91	CA	2079812	EP	0525007
		HK	1002938	SG	46261	US	5602543
		WO	9115739				
US	3805074	CA	1011129	DE	2362935	FR	2212927
		JP	49099082				
JP	60011122						
EP	0087077	DE	3206427	JP	58156837		
US	6822236	US	6750453				

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX